APPLICABILITY OF THE LARGE STONE ASPHALT CONCRETES FOR SURFACE COURSE OF HEAVY-DUTY AIRPORT PAVEMENTS

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ABSTRACT

To construct the highly durable pavement that has a sufficient resistance to plastic flow is very important in airport asphalt pavements, because the pavement has to support approximately 4,000 kN of aircraft weight for a long period. Considering an economic aspect, it is effective for this case to use the asphalt concrete that has a high stability in the surface course and/or binder course, and one of promising mixtures is a large stone asphalt concrete, which has continuous grading with maximum size of more than 25 mm.

In this paper, applicability of the large stone asphalt concrete to the surface course of airport asphalt pavements was evaluated by carrying out laboratory tests and field loading test. In the laboratory tests, the direct tension test and the cyclic bending test were also conducted in addition to standardized asphalt concrete tests. The experimental pavements were constructed and a loading cart with same weight and configuration of Boeing-747 type landing gear was used in the field study.

From the discussion of test results, the following conclusions were obtained.

1. Plastic flow resistance of the large stone asphalt concrete is considerably higher than that of conventional surface materials.
2. Tensile strain at failure and fatigue resistance of the large stone asphalt concrete tend to be somewhat inferior to those of conventional surface materials under the condition of low temperature or fast loading rate.
3. The large stone asphalt concrete with maximum aggregate size of about 30 mm can be applied in surface course of heavy-duty asphalt pavements.

INTRODUCTION

Runways and taxiways in Japanese airports are generally constructed with asphalt pavements. The aircraft load, not only a traffic volume but also a weight from main landing gears, tends to increase in major airports because of rapid growth on demand for aircraft transportation. The weather condition of Japan is generally mild with four distinct seasons, while it is hot and humid in the summer. From these situations surrounding the Japanese airports, rutting is easy to be

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formed at a taxiway or an end of runway where large aircraft travels at slow speed. Rutting is also one of the serious failure forms in airport asphalt pavement and has to be dealt with positively.

To improve a plastic flow resistance in asphalt concrete, polymer-modified asphalt or a gap graded aggregate blend is often adopted in busy road pavements. In airport pavements, however, only modified binder that softening point is risen or temperature susceptibility is gotten dull is occasionally used to surface asphalt concrete, and polymer-modified asphalt has not been applied because of the cost aspect. When such a modified binder is used to surface course of airport asphalt pavements, many hair cracks are sometimes observed instead of plastic flow. This is due to the lack of flexibility in the surface asphalt concrete.

A parallel taxiway at Osaka International Airport constructed with asphalt concrete having straight asphalt binder was a typical example, where heavier aircraft ran repeatedly at slow speed. Severe rutting was observed there only after one year from the opening to traffic, and then overlay works with various kinds of modified asphalt, polymer-modified type was not applied, have been carried out at intervals. In some cases, however, severe cracking has been observed instead of rutting (Takahashi, et al. 2000). It means that a cracking resistance also has to be taken into account in case of improving a plastic flow resistance.

Based on this point of view, the improvement of plastic flow resistance with same flexibility as conventional asphalt concrete in airport asphalt pavements is discussed in this study. Using high-strengthened modified asphalts and applying a large stone asphalt concrete, which has continuous grading with maximum size of 25 mm or more, are found out as the effective material. Modified asphalt, however, has disadvantage concerning the cost aspect. Therefore, applying a large stone asphalt concrete to surface course might be the most promising method. This paper describes applicability of the large stone asphalt concrete in the surface course of airport asphalt pavements. Not only plastic flow resistance but also cracking resistance was examined by both laboratory tests and field tests.

Asphalt concretes used for surface course and binder course in Japanese airport pavements have continuous grading with maximum aggregate size of 13 mm or 20 mm (Civil Aviation Bureau, Ministry of Transport 1999). In this study, two kinds of the large stone asphalt concrete, with maximum aggregate size of 30 mm and 40 mm, were used and compared with conventional surface course materials.

BASIC PROPERTIES OF LARGE STONE ASPHALT CONCRETE

To investigate basic properties of the large stone asphalt concrete, Marshall stability test and wheel tracking test were conducted using continuously graded mixtures with maximum aggregate size of 30 mm and 40 mm. A bending test was also curried out to evaluate the dispersion of density within a thick-compacted layer, since thick-lift construction method would be applied when a large stone asphalt concrete is paved on an actual field.

(1) *Summary of test method*

Fore kinds of asphalt concrete were evaluated in those tests. Two of them were conventional mixtures used in Japanese airport pavements, which had continuous grading with maximum aggregate size of 13 mm or 20 mm, and others were the large stone asphalt concrete, which had continuous grading with maximum aggregate size of 30 mm or 40 mm. Aggregate gradations and asphalt binder contents of each asphalt concrete are summarized in Table 1. Each material is described by the simple symbol, i.e. mixture “A,” “B,” “C” and “D” hereafter. The aggregate gradations were decided from the gradation range standardized in Japanese design manual and ASTM D3515, and asphalt contents are determined from the results of Marshall stability test (National Asphalt Pavement Association 1990). Asphalt binder used in the asphalt concretes was straight asphalt of penetration grad 60 - 80.

Table 1. Aggregate Gradations and Asphalt Content

Sieve (mm)	A (%)	B (%)	C (%)	D (%)
53.0	---	---	---	100
37.5	---	---	100	99.6
26.5	---	100	93.4	---
19.0	100	98.5	---	71.4
13.2	97.4	82.7	68.6	---
4.75	63.3	56.1	44.7	38.8
2.36	42.3	42.1	31.8	28.9
0.6	24.7	24.9	---	---
0.3	15.9	16.1	13.3	12.7
0.15	8.6	8.7	---	---
0.075	5.5	5.5	4.2	4.0
As. Cont.	5.7	5.5	4.6	4.4

Wheel tracking test is standardized only for 50 mm thick specimen. For asphalt concrete with maximum aggregate size of 30 mm or 40 mm, however, the thickness of 50 mm is not sufficient to secure prescribed density in specimen compactions. Because of this, specimens with maximum aggregate size of 30 mm and 40 mm were prepared with both 100 mm and 150 mm in thickness. In addition to those thicknesses, the test was carried out for 50 mm thick specimens with the aggregate size of 13 mm or 20 mm.

To evaluate the flexural strength, strain at failure and the dispersion of density, static bending test was also conducted to all of those asphalt concrete. All of the specimens were prepared in the shape of width of 50 mm, length of 300 mm and thickness of 75 mm. As shown in Figure 1, they were cut out from 300 x 300 x 150 mm asphalt block that was same as the 150 mm thick specimens for wheel tracking test. The bending test was carried out with a span length of 200 mm under the condition of temperature of 0 ºC, 20 ºC and 40 ºC, and loading rate of 1 mm/min and 100 mm/min, namely, six different conditions.

(2) *Test results*

The results of the Marshall stability test are summarized in Table 2. Numbers in [ ] of mixture “A” and “B” indicate the required values which are provided by Japanese Civil Aviation Bureau, and the those of mixture “C” and “D” indicate the recommended values which are decided by National Asphalt Pavement Association (NAPA). The stability and flow of the large stone asphalt concrete cannot be compared to those of conventional asphalt concrete because of the difference in specimen sizes. All results of the each specimen, however, sufficiently satisfied the airport asphalt pavement specification or NAPA recommendation.

Table 2. Result of Marshall Stability Test

Mix.	OAC (%)	Stability (kN)	Flow (1/10 mm)	Air void (%)	Saturation (%)	Residual Stability (%)
A	5.7	12.3 [>8.8]	31 [20-40]	3.1 [2-5]	80.9	95.3 [>75]
B	5.5	15.4 [>8.8]	28 [20-40]	3.3 [2-5]	79.2	89.4 [>75]
C	4.6	36.0 [>19.8]	42 [30-60]	4.1 [3-5]	72.1	85.0 [>75]
D	4.6	31.0 [>19.8]	48 [30-60]	3.9 [3-5]	72.3	85.7 [>75]

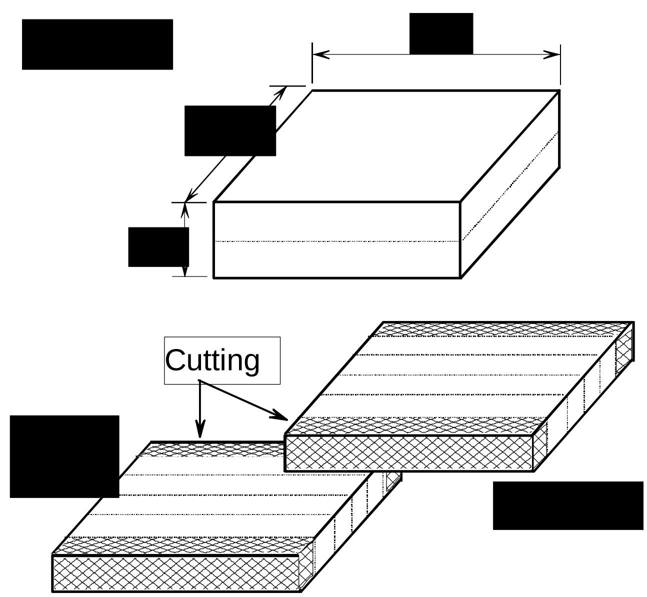


Figure 1. Preparation of Specimens for Bending Test

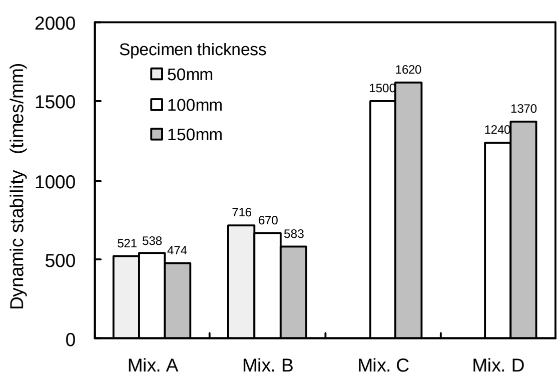


Figure 2. Comparison of Dynamic Stability

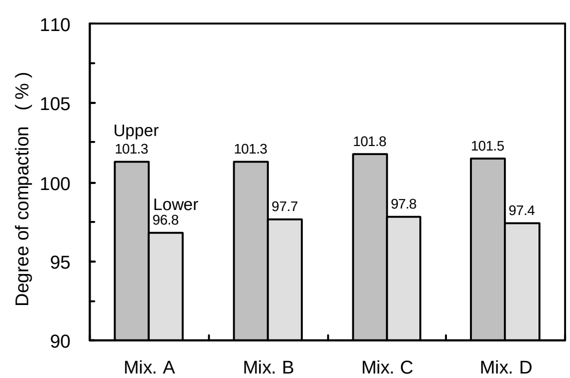


Figure 3. Comparison of Degree of Compaction

It is generally known that a larger aggregate asphalt concrete has higher plastic flow resistance. Difference in the stabilities due to specimen sizes was quantitatively evaluated in the wheel tracking test. Figure 2 shows the results of average dynamic stability calculated from three specimens of each thickness. Increasing the maximum size of aggregate in asphalt concrete increases the dynamic stability among the mixture “A”, “B” and “C”, but the dynamic stability of the mixture “D” is slightly smaller than that of the mixture “C”. For conventional asphalt concretes (mixture “A” and “B”), increasing the specimen thickness tends to decrease the dynamic stability. For the large stone asphalt (mixture “C” and “D”), the dynamic stability of specimen formed with 150mm thickness is larger than that with 100 mm thickness.

The bending tests were conducted at the temperature of 0°C, 20°C and 40°C under the loading rate of 1mm/min and 100mm/min. Asphalt concrete blocks were divided in upper part and lower part, and the test was carried out for specimens of each part. As the results, the flexural strength and the strain at failure are summarized in Table 3. Average values of compaction degree for each part are shown in Figure 3. The flexural strength of the upper part specimens is larger than that of the lower part specimens for all test conditions. The same tendency can be seen in the results on compaction degree. Whereas, on the strain at failure, definite difference cannot be recognized between the upper part specimens and the lower part specimens. The strain at failure for specimens of mixture “C” and “D” was generally smaller than that for specimens of mixture “A” and “B”. The difference of the strain at failure between specimens of mixture “C” and “D” was not recognized in the results.

Table 3. Results of Bending Test

Mix	Temp. (°C)	Loading rate : 1mm/min				Loading rate : 100mm/min			
		Flexural strength (kgf/cm^2)		Strain at failure (x10^{-3})		Flexural strength (kgf/cm^2)		Strain at failure (x10^{-3})	
		Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
A	0	93.7	72.9	32.4	28.0	108.0	77.2	8.6	7.5
	20	7.6	7.5	44.9	44.8	53.1	42.4	32.2	36.9
	40	1.6	0.9	33.8	31.6	5.9	5.2	37.3	36.0
B	0	100.6	71.4	22.1	22.0	101.5	72.2	7.5	6.7
	20	7.7	6.9	43.6	42.3	54.9	42.9	35.7	39.1
	40	1.7	0.9	30.5	28.5	6.5	4.7	46.5	38.9
C	0	99.1	73.8	20.8	15.7	101.8	75.5	8.6	7.8
	20	8.0	6.3	30.4	27.6	54.9	40.4	28.0	30.9
	40	1.4	1.1	25.6	24.4	6.1	3.8	27.5	31.1
D	0	99.2	66.5	16.3	14.4	89.7	67.7	6.5	6.9
	20	7.7	6.1	30.4	29.2	58.6	33.3	28.8	21.5
	40	1.6	0.9	28.2	25.8	5.7	3.8	33.9	34.4

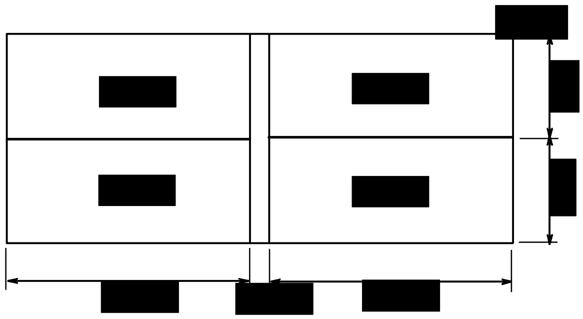


Figure 4. Plan of Experimental Pavement

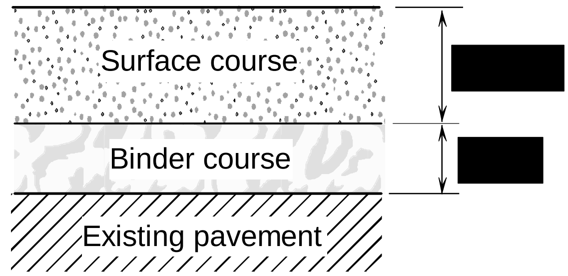


Figure 5. Cross Section of Experimental Pavement

(3) *Remarks*

Findings about basic property of the large stone asphalt concrete are summarized from comparison with conventional asphalt concrete as follows:

1. Plastic flow resistance for the large stone asphalt concrete is fairly large even in thick surface course. The large stone asphalt concrete with maximum aggregate size of 30 mm had the highest plastic flow resistance in the test.
2. The strain at failure for the large stone asphalt concrete is slightly smaller, and it suggests that further study about the durability of the large stone asphalt concrete is needed.

EVALUATION BY LOADING TESTS

After the laboratory test was finished, a field study was carried out by conducting the repeated loading test. The evaluation of plastic flow resistance based on the laboratory test was not sufficient for airport pavements, since wheel tracking test was primarily developed for road pavements and the tire pressure of testing machine was obviously smaller than that of aircraft. In the in site loading test, the same weight and configuration of Boeing-747 type dual-tandem landing gear was used.

(1) *Test field and testing method*

A test field was constructed using the same asphalt mixtures as those evaluated in the laboratory tests; namely, the four kinds of asphalt concrete shown in Table 1 were applied to surface course of the experimental pavement. Figure 4 shows a plan of the experimental pavement, which is 62 m long and 7 m wide. It was divided four sections for each surface asphalt concrete. The experimental pavement was composed of newly laid binder course and surface course on the existing asphalt pavement. The pavement structure is shown in Figure 5. The binder course material was same in all sections and has conventional mix proportion with maximum aggregate size of 20 mm widely used in Japanese airport. Therefore, each test section was different in only the surface course asphalt concrete.

Surface course and binder course were paved using an asphalt finisher and compacting rollers. Vibratory roller was also used for surface course paving to secure enough density even in one 100 mm thick layer (Takahashi, et al. 2001). After the construction, core samples were cut through surface and binder courses and the density was measured at upper part and lower part of surface

Figure 6. Loading Cart Having B-747 Landing Gear

Table 4. Results of rut depth

Section	Rut depth (mm)		
	Sec. a-a	Sec. b-b	Average
Mix. A	2.0	2.0	2.0
Mix. B	3.5	4.5	4.0
Mix. C	1.5	1.5	1.5
Mix. D	2.0	3.0	2.5

Table 5. Results of evenness

Section, Location	Stand. Dev. (mm)		Difference
	Before (a)	After (b)	(b)-(a) (mm)
Mix. A I	2.15	2.36	+0.21
II	2.28	2.17	-0.11
III	1.99	2.19	+0.20
Average	2.14	2.24	+0.10
Mix. B I	1.67	1.86	+0.19
II	2.06	1.89	-0.17
III	2.20	1.47	-0.73
Average	1.97	1.74	-0.24
Mix. C I	0.99	1.10	+0.11
II	1.74	1.66	-0.88
III	2.20	2.25	+0.05
Average	1.64	1.67	+0.03
Mix. D I	1.15	1.06	-0.09
II	1.42	1.65	+0.23

course. The difference between upper part density and lower part density was not recognized for all sections.

Repeated loading tests were then conducted using a loading cart that could apply the same loads as aircraft landing gear of Boeing-747. Figure 6 shows the view of the loading cart, which contains aircraft landing gear in the middle of cart. The weight of load was adjusted to be the landing gear weight of 910 kN. Loading was repeated to one thousand times for each section in the longitudinal direction. Sectional profile and longitudinal evenness were measured before and after the repeated loading at the same location. Cross section profile measurement carried out at two locations and longitudinal evenness measurement carried out at three locations for each test section.

(2) *Test results*

The results of rut depth calculated from cross section profile data are summarized in Table 4. It is hard to find out the difference in the formed rut depth among the mixtures. The rut depth of the mixture “C” was the smallest in those mixtures, this was the same result as the above-mentioned wheel tracking test. The mixture “A” had the lowest plastic flow resistance on the wheel tracking test, but the same result could not be found on this test. As a general result, it was recognized that the large stone asphalt concrete has superior plastic flow resistance to conventional asphalt concrete.

The results of longitudinal evenness measured before and after the loading are summarized in Table 5. Most differences in those before and after the loading are not found. All the result values were a little large as an airport pavement surface. This was because the experimental pavement did not have enough length to pave with the asphalt finisher. Therefore, it should be concluded that the large stone asphalt concrete was not inferior to conventional asphalt in a surface evenness.

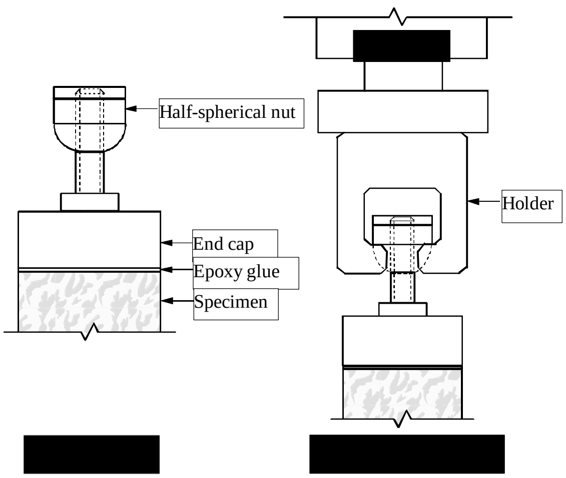


Figure 7. Apparatus for Direct Tension

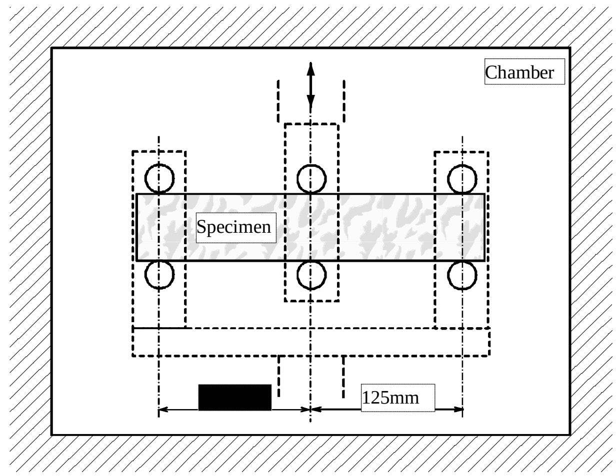


Figure 8. Loading Way of Cyclic Bending Test

(3) *Remarks*

In the repeated loading test, quantitative difference in plastic flow resistance between the large stone asphalt concrete and conventional asphalt concrete could not be found out, since temperature and number of loading repetitions were not sufficient for comparative evaluation. However, superior plastic flow resistance of the large stone asphalt concrete could be confirmed by the loading test of the same weight of Boeing-747 type landing gear. It was also made sure that there was no problem on the change of longitudinal evenness by repeated loading and the construction using ordinary paving machines.

EVALUATION FOR DURABILITY

As the feasibility of the large stone asphalt concrete was recognized in the field study, various elaborated tests such as direct tension test and cyclic bending fatigue test were conducted to evaluate their durability properties in detail. Failure resistance against cyclic loading, in particular, had to be confirmed because strain at failure for the large stone asphalt concrete was smaller in the static bending test.

Another static bending test, raveling test and Cantabro test were also curried out in the evaluation for durability, but only direct tension test and cyclic bending test are mentioned in this paper. Specimens used for all of the tests were taken from the each surface course of experimental pavements, shown in Figure 4, as avoiding the passage position of loading tires.

(1) *Test methods*

Direct tension test for asphalt concrete has been conducted by only a small number of researchers in Japan. Therefore, test details such as specimen size, testing equipment and testing

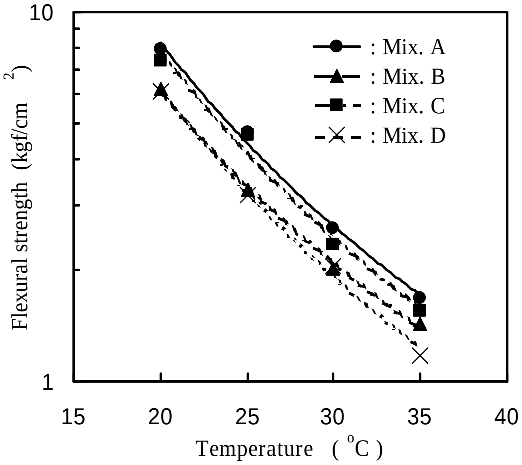


Figure 9. Flexural strength vs. temperature

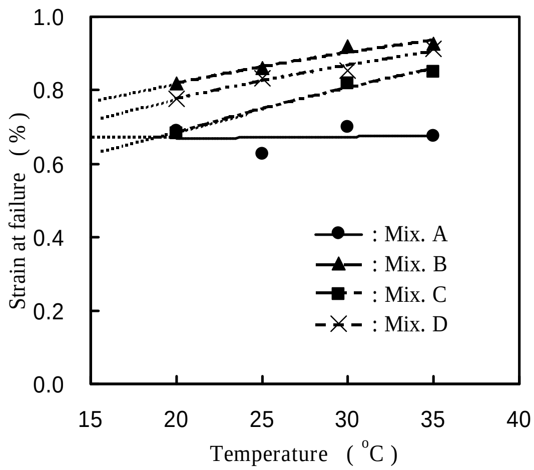


Figure 10. Strain at failure vs. temp.

changed in parametric, four or five ways with the range from 1000 x 10^{-6} to 2500 x10^{-6} for the amplitude, and -10°C, 0°C, 5°C and 10°C for the temperature. Specimens were prepared in the shape of 50 mm x 75 mm x 300 mm bars.

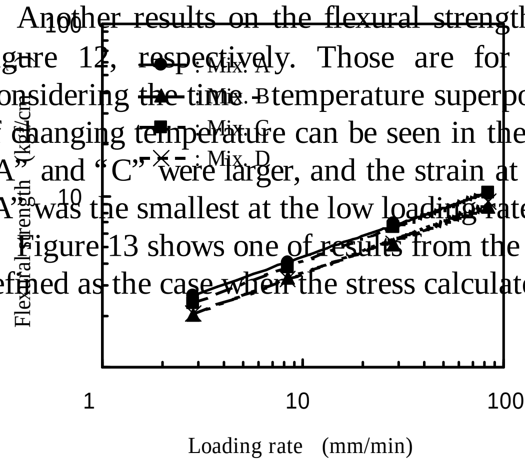
Clamps at loading and supporting points got loose little by little with increasing number of repeated loading because of the permanent deformation of specimen, but it was avoided by using auto-tightening motor system for the clamps.

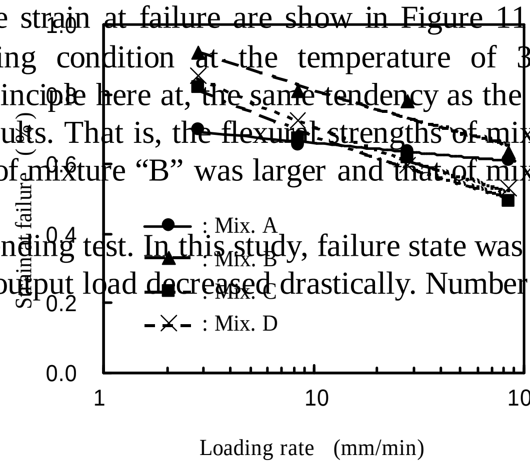
(2) *Test results*

On dealing with the result of direct tension test, failure state was defined at the peak point of output load value, and the flexural strength and the strain at failure were calculated as well as static bending test. Figure 9 and Figure 10 show the flexural strength and the strain at failure, respectively, for the asphalt concrete under the loading rate of 2.81 mm/min. The flexural strengths of mixture "A" and "C" were slightly larger than those of other mixtures. On the other hand, the strain at failures of mixture "B" and "D" were larger, and that of mixture "A" was the smallest. As the change of the strain at failures on mixture "A" for the temperature was very small, howe[illegible] the strain at failures of the large stone asphalt concrete was supposed to be smaller than that of conventional concrete in the low temperature rage such as blow 20°C. It was seen that the strain at failure of the large stone asphalt concrete was smaller than that of conventional mixtures in the static bending test, but the same result was not derived from the direct tension test. This was because the degree of compaction for the large stone asphalt concrete specimen prepared in laboratory was not as high as that compacted by actual heavy vibratory roller.

Another results on the flexural strength and the strain at failure are show in Figure 11 and Figure 12, respectively. Those are for the testing condition at the temperature of 30°C. Considering the time - temperature superposition principle here at, the same tendency as the case of changing temperature can be seen in the both results. That is, the flexural strengths of mixture "A" and "C" were larger, and the strain at failures of mixture "B" was larger and that of mixture "A" was the smallest at the low loading rate.

Figure 13 shows one of results from the cyclic bending test. In this study, failure state was defined as the case when the stress calculated from output load decreased drastically. Number of





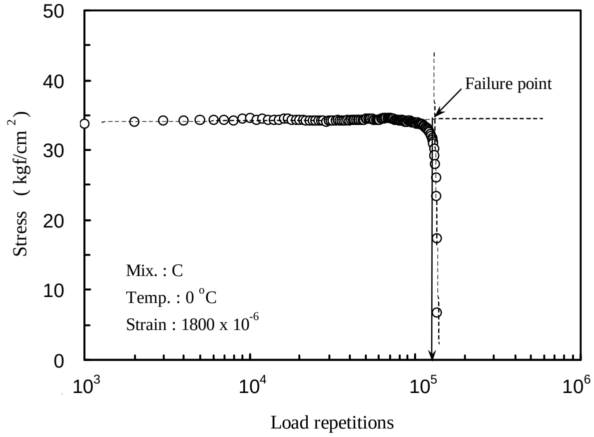
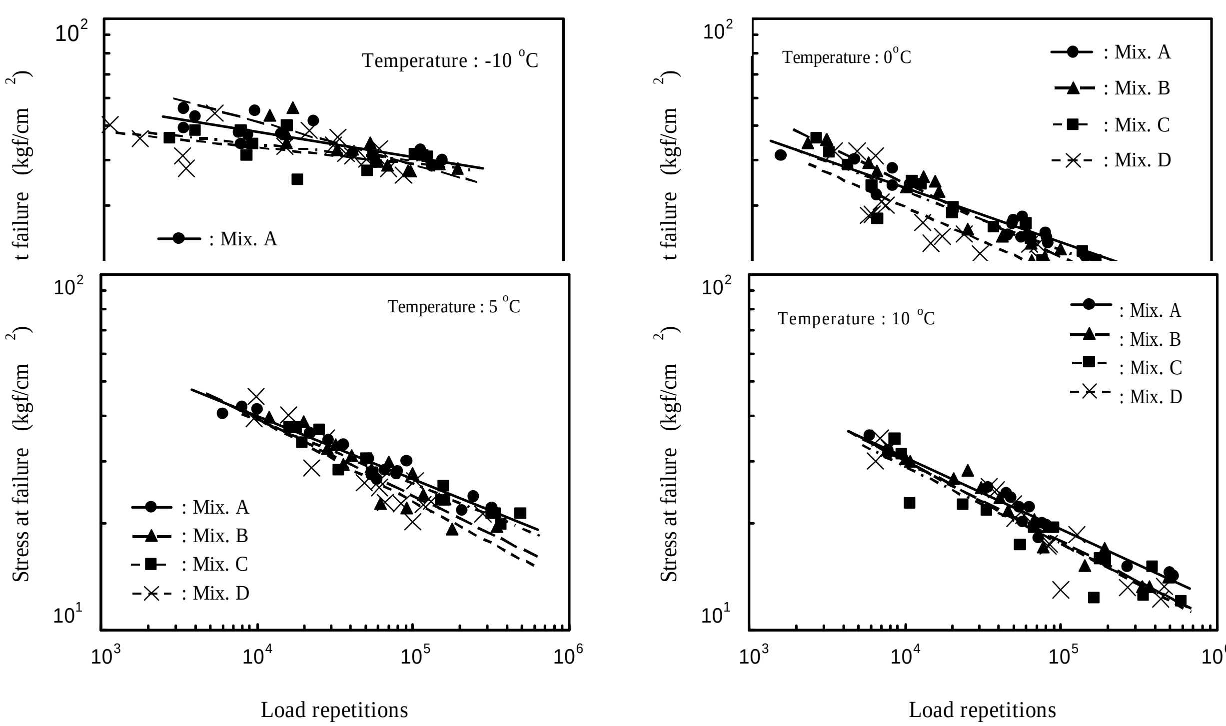


Figure 13. Decision of a stress at failure

repetition and stress at failure were derived by intersecting two regression lines, which were decided from the stress data before and after the drastic decrease.

The results of relationship between number of repetition and stress at failure for the each asphalt concrete under a temperature of –10°C are shown in Figure 14. Figure 15, Figure 16 and Figure 17 show the same results under the temperature of 0°C, 5°C and 10°C respectively. Each symbol represents individual result from one test sample and a straight line expresses the regression of the same asphalt concrete data. For the temperature of –10°C, the regression lines of the large stone asphalt concrete were located at lower position than those of conventional mixture. This meant that the fatigue resistance of the large stone asphalt concrete was inferior to that of conventional concrete. For the temperature of 0°C, the difference in the fatigue resistance among mixtures “A”, “B” and “C” was not clear but fatigue resistance of mixture “D” was obviously inferior to others. The fatigue resistance of mixture “A” and “C” were superior under the temperature of 5°C. The difference in fatigue resistance among all asphalt concretes was not seen in the result at the temperature of 10°C. In the results under the temperature of 0°C and 5°C, the fatigue resistance of mixture “C” was superior to that of mixture “D.”



The entire result of the fatigue resistance comparison was evaluated as follows. Fatigue resistance of the large stone asphalt concrete was somewhat inferior to that of conventional asphalt concrete, and mixture “D” was particularly inferior. This tendency appeared in the condition of lower temperature and the difference in fatigue resistance was not seen at the temperature of 10°C. However, mixture “C” had almost the same fatigue resistance as conventional asphalt concrete.

(3) *Remarks*

Findings from the direct tension test and cyclic bending test using specimens taken from experimental pavement are summarized as follows:

1. The flexural strengths of mixture “A” and “C” were slightly larger than those of other mixtures. The strain at failure of the large stone asphalt concrete is smaller than that of conventional asphalt concrete in the condition of low temperature or high loading rate.
2. The strain at failure of conventional surface asphalt concrete (mixture “A”) is not changed drastically irrespective of changing temperature or loading rate, but the strain at failure is small at the condition of high temperature or low loading rate.
3. Fatigue resistance of the large stone asphalt concrete is somewhat inferior to that of conventional asphalt concrete at a low temperature.
4. The large stone asphalt concrete (mixture “C”) has almost the same fatigue resistance as conventional asphalt concrete.

CONCLUSIONS

To improve a plastic flow resistance of airport asphalt pavements, application of the large stone asphalt concretes to the surface course was discussed in this study. Fundamental laboratory tests, repeated loading tests using the same weight of the large aircraft and durability evaluation tests were conducted for recognizing a feasibility of the large stone asphalt concrete.

The following conclusions were obtained on the applicability of large stone asphalt concretes to heavy-duty airport pavements.

1. Plastic flow resistance of the large stone asphalt concrete is considerably higher than that of conventional materials.
2. Tensile strain at failure, that is, flexibility for tension and fatigue resistance of the large stone asphalt concrete are somewhat inferior to those of conventional materials at the condition of low temperature or fast loading rate.
3. The large stone asphalt concrete with maximum aggregate size of 30 mm can be applied in surface course of heavy-duty asphalt pavements.

As a farther study, another mix design procedure has to be discussed to obtain more suitable mix proportion for surface mixture of airport pavement. Severer field endurance test is also needed to evaluate the serviceability.

ACKNOWLEDGEMENT

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